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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This Test Operations Procedure (TOP) provides methods for determining the electromagnetic compatibility of communications-electronics (C-E) equipment. It describes procedures to determine that C-E equipment and systems incorporate the best available technology for securing freedom from interference and that concepts for their use assure mutual compatibility with the resultant electromagnetic environment.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-105
*Test Operations Procedure 6-2-560
AD No.

12 October 1979

COMPATIBILITY, ELECTROMAGNETIC

1. SCOPE.

1.1 Electromagnetic Compatibility (EMC). EMC must be assessed by testing of all equipment or systems generating or responding to electromagnetic energy. The testing is required to assure that the equipment can be operated in its expected electromagnetic environment without unacceptable degradation of its own or other friendly equipment's operational performance.

1.2 Objective. The objective of this TOP is to provide evaluation techniques which help to provide assurance that communications-electronics (C-E) equipments and systems incorporate the best available technology for securing EMC. For non-C-E items see TOPs 2-2-613 and 6-2-542.

1.3 Limitations. EMC determinations are made by the application of performance measurements, simulation, and analytical techniques.

2. FACILITIES AND INSTRUMENTATION.

2.1 General. Since special facilities and instrumentation are required, the capabilities of the Electromagnetic Environmental Test Facility (EMETF) of the U. S. Army Electronic Proving Ground (USAEPG) are described. Equivalent facilities may be used.

*This TOP supersedes MTP 6-1-006, 31 July 1970.

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2.2 Facilities.

2.2.1 Instrumented Workshop. The Instrumented Workshop (IWS) utilizes screened rooms, standard test equipment, and special instrumentation for evaluations of equipment or systems in the hardware stage. Dynamic performance characteristic curves are produced for receivers subjected to radio frequency (RF) interference, including jamming signals. This facility also provides controlled laboratory conditions to acquire operational performance data on equipment for use in development and validation of the library of computer programs.

2.2.2 Spectrum Signature Facility. The Spectrum Signature Facility includes both fixed and mobile laboratories that are equipped with instrumentation to perform all spectrum signature and specialized data measurements of equipment under either carefully controlled laboratory or semicontrolled field conditions.

2.2.3 Voice Scoring Facility. The Scoring Facility is designed to measure the performance of C-E systems. This facility measures information transfer and permits the establishment of equipment performance data.

2.2.4 Weapon System Electromagnetic Environment Simulator. The Weapon System Electromagnetic Environment Simulator (WSEES) is a highly versatile measurement tool comprising a programable RF generator, an RF absorption room, a steerable platform, and other support equipment necessary to simulate complex electromagnetic environments and develop scoring data for systems operating in the microwave frequency bands. RF signals are produced which are exact duplicates of those that would be expected in the real-world environment.

2.2.5 Field Facility. The Field Facility consists of a fixed test site for centralized test control, numerous locations for mobile testing, a mobile electronic countermeasures environment generator installation, a mobile and semimobile environment analysis system, and an environment generator consisting of tactical C-E transmitters. Testing capabilities include cosite interference evaluations, RF radiation tests, open-field emission tests, and susceptibility measurements.

2.2.6 Library of Computer Programs. The library comprises a selection of computer programs used as analytic tools for analyses of operational concepts, systems, and equipments. Outputs are systems effectiveness scores for analog systems, probability of bit error for digital systems, and electromagnetic radiation (EMR) levels for equipment susceptibility and hazard analyses. Data obtained from tests or measurements conducted in one or more of the empirical facilities are used as inputs to these computer programs.

2.3 Instrumentation.

2.3.1 Simulation Techniques. Simulation of small- and large-scale C-E systems in realistic environments is based on a library of computer models. This library includes the following:

a. Combinatorial Analysis Technique Model aids in evaluating EMC of frequency hopping radars which use frequencies from the same assignment list.

b. Cosite Identification Model extracts from a test bed those equipments which are within specified distances from each other.

c. EMR Model determines electromagnetic radiation levels at specific sites in a deployment of C-E equipment. The model output identifies maximum levels of field strength sorted by frequency band and modulation type. In addition, typical scenarios of action and counter action, deployment methodology, frequency assignment methodology, code book, troop list and C-E equipment deployment parameters are included in validated test beds which are supplied by the Communications Research and Development Command (CORADCOM), formerly the U. S. Army Management Systems Support Agency (USAMSSA). These data are combined with the library of computer models to perform a wide variety of simulations.

2.3.2 Measurement Techniques. Data recording collection and performance scoring shall be for both analog and digital communications systems. The system will perform many measurements of MIL-STD-449D[1] spectrum signature measurements automatically. Performance scoring of weapon systems and microwave equipment reproduces the varying multisignal environments in which most weapon systems must operate, while measuring system reaction to that environment. Quantification of human operators and their responses to communications equipment must demonstrate the ability to numerically relate equipment performance in varying interference and jamming environments to operational performance. Mobile test instrumentation permits EMC testing in a number of different locations, as indicated by the intended use of the equipment under test.

2.3.3 Analytical Techniques. Analyses may be performed at various levels, depending on the requirements of the individual developers or agencies. These may include--

a. "Desk-top" analyses, which may require only a search of certain data files and recommended actions based on engineering judgment.

b. Intermediate-sized analyses, which may be supported by computer calculations and data file searches.

[1]/MIL-STD-449D, Radio Frequency Characteristics, Measurement of.

c. Major simulations requiring extensive equipment measurements, a test bed, and exercise of the desired computer models.

3. PREPARATION FOR TEST.

3.1 Facilities and Instrumentation. Assure that the facilities and instrumentation are available as required for individual test. Decide upon the test technique to be employed, whether by simulation models or by measurement or analysis techniques.

3.1.1 Simulation Models. Select a model and obtain approval from the test sponsors for use for the equipment under test.

3.1.2 Measurement. Have the instruments and test equipment for data collection properly calibrated and assure they have the range and accuracy needed to perform the test. Obtain or train scorers for the Scoring Facility.

3.1.3 Analysis. Assure that analytical skills are available and that sufficient data have been provided by test sponsors regarding the tactical employment of the test item. Determine the operational environment appropriate for the test item.

3.2 Data Required. Record the following:

a. Plan of deployment.

b. Frequencies, power levels, and modes of the test item to be used or explored.

c. Any special conditions considered.

d. Normal operating characteristics of the test item.

4. TEST CONTROLS.

4.1 Test Officer.

a. Observe conduct of measurements to insure proper procedures are followed.

b. Review results to insure consistency and repeatability.

c. Insure the approval of model applications by the test sponsor.

d. Review the analytical process to insure that results are consistent with test objectives and criteria.

4.2 Report Review. Make a report review by engineers and military experts not directly connected with the test in progress.

5. PERFORMANCE TESTS.

5.1 Electromagnetic Compatibility (RF).

5.1.1 Objectives. The objectives of this subtest are--

a. To determine whether the test item can degrade the performance of other C-E equipment in the intended operational electromagnetic environment.

b. To determine whether C-E equipment in the intended operational electromagnetic environment degrades the performance of the test item.

5.1.2 Method (Analytical).

5.1.2.1 Effects of the Test Item on the Environment.

a. Obtain electromagnetic interference (EMI) data (MIL-STD-462)[2/] on the test item from tests previously performed, if available.

b. Note the frequency and emission levels of conducted and radiated emissions which exceed the MIL-STD-461A,[3/] Notice 4, specification levels. If EMI data are not available, perform an analysis based on engineering judgment, using equipment characteristics.

c. Perform an equipment search, which will include sources appropriate to the concept of employment of the test item, to determine those C-E equipments which operate at the frequencies noted above and the deployment distances and angle from the test item. The following are sample sources to be searched:

(1) A test bed developed by the CORADCOM and approved for use by the Department of the Army and the test sponsor.

(2) Frequency Allocation to Equipment File (FAEF).

(3) Other available listings (national and international) of C-E equipments appropriate to the geographical area of interest.

d. Obtain available susceptibility measurement data for the equipment identified in paragraphs 5.1.2.1a, b, and c.

[2/]MIL-STD-462, Electromagnetic Interference Characteristics, Measurements of.

[3/]MIL-STD-461A, Electromagnetic Interference Characteristics, Requirements for Equipment.

e. Consider all appropriate power levels and deployment distances which can reasonably be expected to occur in a typical deployment from the method described in paragraphs 5.1.2.1a, b, and c.

5.1.2.2 Effect of the Environment on the Test Item.

a. Obtain EMI data on the equipments listed as a result of the search performed in paragraphs 5.1.2.1a, b, and c.

b. Review the data to determine the susceptibility of the test item to conducted and radiated interference.

c. Note any conducted and radiated emission susceptibility indication which exceeds the MIL-STD 461A, Notice 4, specification level for frequency and emission level.

d. Perform an equipment search of the sources identified by paragraphs 5.1.2.1a, b, and c to determine those C-E equipments which operate at the susceptible frequencies of the test item, and their deployment distances and angles from the test item.

e. Obtain the MIL-STD-449D measurement data and other spectrum signature and emission data for the equipments identified by the procedures of paragraph 5.1.2.2a.

f. Consider all appropriate power levels and deployment distances which can reasonably be expected to occur in a typical deployment.

5.1.3 Data Required (Analytical). Record the following:

a. EMI data, in the RF region, for the test item.

b. List of C-E equipments (paras 5.1.2.1a, b, and c) with which the test item can be expected to interfere, and their frequencies of operation.

c. Susceptibility test data for C-E equipments identified in paragraph 5.1.3b.

d. List of C-E equipments (para 5.1.2.2a) which can be expected to interfere with the test item, and their frequencies of operation.

e. Spectrum signature and emission data, if available, for the equipments identified in paragraph 5.1.3d.

f. Geographical disposition of equipment identified in paragraphs 5.1.3b and d.

g. Deployment distances between the test item and equipments identified in paragraphs 5.1.3b and d.

5.1.4 Method of Simulation.

a. Obtain information on the concept of employment of the test item and determine the tactical situation(s) that should be simulated. Determine this through coordination with the project sponsor or equipment user.

b. Develop or obtain a scenario and test bed description suitable for the concept of employment.

c. Generate a realistic frequency assignment for all communication devices and nets in the tactical deployment, using a technique appropriate to the project.

d. Select a computer model for the planned situation. Provide additional programing as necessary to simulate the complete planned situation.

e. Consult appendix D for supplemental information.

f. Conduct the test.

5.1.5 Data Required (Simulation). Record the following:

a. Information from paragraph 3.2.

b. Test bed description with scenario.

c. Activation schedule of links or systems (see app D).

d. Weighting provided on selected critical links or systems.

e. Narrative description of interference and its effect; provide sources, frequencies, time intervals, percent of lost information, and other factors of the specific scenario which would be important to the tactical situation simulated.

5.1.6 Method (Measurement).

a. Use the same approach for the field or bench tests as indicated in paragraph 5.1.4.

b. Select the facility (see para 2.2).

c. Arrange appropriate interference to represent the tactical situation decided upon.

d. Arrange for required frequency authorizations, if needed.

e. Consult appendix D for additional methodology on the operating techniques and requirements.

f. Check the operation of each test item or equipment according to its specifications.

g. Check the operation of the test item without any electromagnetic interference in the environment.

h. Operate the arranged environment in phases or links, following the techniques of appendix D.

5.1.7 Data Required (Measurement). Record the following:

a. Operational characteristics of the test item without interference.

b. Plot of the arrangement of equipments.

c. Power level, frequency, and coordinated time of operation of each item, providing the interference pattern at any time during the test.

d. Effect of the environment on the test item during each "period" of operation. Provide the percentage of useful information obtained, or useful action, during each period, with the test item utilized as it would be in the simulated tactical situation.

e. Angle of interfering equipment from the test item and range, as appropriate. List power level, frequency, and beamwidth, as appropriate, for the interferer.

f. Meteorological conditions at the test site.

5.2 Electro-Optical/Infrared (EO/IR) Compatibility.

5.2.1 Objectives. The objectives of this subtest are--

a. To determine whether radiations from the test item are detectable by passive EO/IR devices.

b. To determine whether the test item is susceptible to incident energy beams in the EO/IR frequency region.

5.2.2 Method.

5.2.2.1 Effect of the Test Item on the Environment.

a. Obtain electromagnetic compatibility (EO/IR) emission data from previous subtests conducted during other phases of the project.

b. To determine those EO/IR devices which operate at the critical wavelengths contained in the data and which will be deployed at an effective distance and angle from the test item in the probable tactical situation, perform a search of equipment/units in the following sources:

(1) The appropriate approved test bed.

(2) Frequency Allocation of Equipment, File (FAEF).

(3) Other available listings (national and international) of EO/IR devices appropriate to the geographical area of interest.

c. Obtain available performance measurement data for the equipment identified in paragraphs a and b above.

d. Consider all appropriate power levels and deployment distances which can reasonably be expected to occur in a typical deployment for the method described in paragraphs a and b above.

5.2.2.2 Effect of the Environment on the Test Item.

a. Obtain electromagnetic compatibility (EO/IR) susceptibility data from tests previously performed.

b. Perform an equipment search of the sources identified in paragraph 5.2.2.1 to determine those EO/IR devices which operate at the susceptible wavelengths of the test item and their deployment distance and angle from the test item.

c. Obtain EO/IR emission characteristics data for the devices identified by the procedures of paragraphs a and b above.

d. Consider all appropriate power levels and deployment distances which can reasonably be expected to occur in a typical deployment in the method described in paragraphs a and b above.

5.2.2.3 Field Verification Tests.

a. General. Perform field tests to verify the results from paragraphs 5.2.2.1 and 5.2.2.2.

b. EO/IR Compatibility Test.

(1) Perform this test in a field facility which has been prepared with an arrangement of other EO/IR devices typical of the expected tactical situation.

(2) Use the test item as it would be used in this situation but without any interfering beams.

(3) Turn on other selected interfering beams and direct them toward the test item, or operate them in a sweep mode if that is representative.

(4) Operate the test item when it is being illuminated. Repeat the operation a sufficient number of times to insure a statistical validity described by 95-percent confidence bounds on stated tolerances about an average success rate. These tolerances at a 95-percent confidence level imply a minimum number of trials. If the test is unsuccessful because insufficient data were allowed, then that statistical explanation should accompany the test results. Vary the range, height, angle, wavelength, power level, and so forth as appropriate for the items.

c. Detectability of the Test Item.

(1) For EO/IR devices, position a suitable detector at former interferer locations.

(2) Operate the test item from its regular position and as it was operated in earlier subtests.

(3) Inform the operator of the detector when the test item is active.

(4) Request the operator of the detector to record the detection or nondetection of the test item.

5.2.3 Data Required. Record the following:

a. Plot of the test item location and of each item of equipment used.

b. Special characteristics of deployed items, including power level, frequency, duty cycle, and so forth.

c. Number of correct operations of the test item.

d. Estimate of optical visibility (m).

e. Detection device parameters, to include--

(1) Wavelength for maximum sensitivity

(2) Viewing angle (rad)

(3) Height (m)

(4) Range to test item (m)

f. Complete narrative description of all interferences or detections.

6. DATA REDUCTION AND PRESENTATION.

6.1 Electromagnetic Compatibility (RF).

6.1.1 Effect of Test Item on the Environment. Use EMI measurement data (in the RF region), geographical deployment data, equipment separation distances, and the appropriate propagation path loss model (the near-field propagation model and the modified Longley-Rice irregular terrain propagation path loss model) for the calculations to determine whether RF radiated emissions from the test item in excess of MIL-STD-461A, Notice 4, limits exceed the radiated susceptibility levels of other C-E equipments in the intended EM environment at the specified separation distances. Plot all emissions for comparison.

a. Identify and define the paths of conducted emissions (from the test item to other C-E equipments in the environment) in excess of MIL-STD-461A, Notice 4, limits.

b. Identify and discuss coupling and loss mechanisms.

c. Perform calculations to determine whether these conducted emissions exceed the conducted susceptibility levels in the intended operational EM environment.

d. Plot and explain results.

6.1.2 Effect of Environment on the Test Item. Perform an analysis similar to that of paragraph 6.1.1 above to determine whether emission levels from other C-E equipments in the environment will exceed the measured susceptibility levels of the test item at the test item locations for the separation distances found. In this analysis, consider emissions at the tuned frequencies of the other C-E equipment as well as radiated emissions in excess of the MIL-STD-461A, Notice 4, limits.

6.2 EO/IR Compatibility.

6.2.1 Effect of Test Item on the Environment. Use EMC (EO/IR) data, geographical deployment data, equipment separation distances, and the appropriate propagation path loss model for the calculations to determine whether EO/IR emissions from the test item exceeded the radiated detectability levels of other EO/IR devices in the intended EM environment at the specified separation distances. Plot emissions for comparison.

6.2.2 Effect of Environment on the Test Item. Perform an analysis similar to that of paragraph 6.2.1 above to determine whether emission levels from other EO/IR devices in the environment will exceed the measured susceptibility levels of the test item at the test item locations for the separation distances found. In this analysis, consider emissions at the primary emission wavelength of the other EO/IR devices as well as spurious and harmonic emissions.

6.2.3 Field Verification Tests. Perform an analysis similar to that of paragraphs 6.2.1 and 6.2.2 above.

6.2.4 Detectability. Use the deployment data, test item parameters, and detector equipment parameters to evaluate the signals (if any) received at the detector.

6.3 Data Forms. Sample data forms are included in appendix A.

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DATA TABLE
FREQUENCY USAGE SUMMARY

Frequency Band	Number of Frequencies Available From Resource	Number of Frequencies Utilized

DETECTION

Description of Test Item	Detector			Range to Test Item	Description of Results
	Wave-length	Viewing Angle	Height		

MEASUREMENT TESTS (INTERFERING ITEMS)

Background Equipment					Test Item		
Item	Power	Freq	Angle (field)	Time On	Power	Freq	(Other)

ANALYTICAL DATA

Test Item EMI Data	Test Item May Interfere With These Equipments			Equipment Which May Interfere With Test Item			Comments
	Name	Freq	Suscep Data	Name	Freq	Spec Sig Data	

COMPATIBILITY DATA

Tuned Frequency:							
Desired Signal (S)		Interfering Signal (I)					
Receiver Bandwidth (kHz)	Level (dBm)	Frequency (MHz)	Level (dBm)		Δf (MHz)	S/I (dB)	
			For Data Error	For Data Loss		For Data Error	For Data Loss

Δf (MHz) = Interferer Frequency Minus Link Frequency

APPENDIX B
CHECKLIST

I. FACILITIES AND INSTRUMENTATION

A. FACILITIES REQUIRED FOR TEST

Have facilities been scheduled? ______

B. INSTRUMENTATION

1. Simulation Techniques

Has guidance for proper computer model selection been established? ______

2. Measurement Techniques

Has guidance for proper measurement, data recording, and performance scoring technique selection been established? ______

3. Analytical Techniques

Has guidance for proper analytical technique selection been established? ______

II. PREPARATION FOR TEST

A. FACILITIES AND INSTRUMENTATION

1. Simulation

a. Have proper computer simulation models been selected? ______

b. Has model application been approved by test sponsor? ______

2. Measurement

a. Have proper measurement data collection and performance scoring instruments been selected? ______

b. Are instruments properly calibrated? ______

3. Analysis

Have proper analyses been selected for the different required outputs? ______

B. DATA REQUIRED

1. Have data sheets been prepared? ______
2. Are they complete? ______
3. Have the normal operating characteristics of the test item been established? ______
4. Have all test item frequencies, powers, and modes which are to be used been itemized? ______
5. Have all data on test item, test equipment, and ancillary equipment been recorded? ______
6. Have operating conditions, modes, control settings, loads, and terminations been recorded? ______
7. Have location, date, time, operator names, all test designators, and test conditions been recorded? ______

III. TEST CONTROLS

1. Is test officer present to observe proper measurement procedures? ______
2. Is test officer satisfied that results are consistent and repeatable? ______
3. Have engineers and military officers not directly connected with the test reviewed the report? ______

IV. PERFORMANCE TESTS

A. ELECTROMAGNETIC COMPATIBILITY (RF)

1. Have all system functions been exercised to determine the measured RF electromagnetic compatibility of the test item? ______
2. Have all system functions been simulated in the selected computer model to determine the RF electromagnetic compatibility of the test item? ______
3. Have all system functions been exercised analytically to obtain the RF electromagnetic compatibility effects of the test item on the environment? ______
4. Have all system functions been exercised analytically to obtain the RF electromagnetic compatibility effects of the environment on the test item? ______

B. ELECTRO-OPTICAL/INFRARED (EO/IR) COMPATIBILITY

1. Have all system functions been exercised to determine the measured EO/IR compatibility of the test item? ______
2. Have all system functions been simulated in the selected computer model to determine the EO/IR compatibility of the test item? ______
3. Have all system functions been exercised analytically to obtain the EO/IR compatibility effects of the test item on the environment? ______
4. Have all system functions been exercised analytically to obtain the EO/IR compatibility effects of the environment on the test item? ______

V. DATA REDUCTION AND PRESENTATION

1. Have data minimization and organization techniques been described? ______
2. Have EMC computer model techniques and parameters been described? ______
3. Are all data available? ______
4. Have all data been reduced? ______
5. Has amount of data presented been minimized? ______
6. Have equipments listed in all source documents been considered? ______

   a. Deployment ______
   b. Frequency Allocation to Equipment File (FAEF) ______
   c. Other ______

7. Is data presentation clear? ______
8. Have the objectives and criteria been answered with the analysis? ______

APPENDIX C
DESCRIPTION OF THE EMETF

The Electromagnetic Environmental Test Facility (EMETF) is a Government-operated, contractor-supported facility of the US Army Electronic Proving Ground (USAEPG), Fort Huachuca, Arizona, a testing activity of the US Army Test and Evaluation Command. The primary mission of the EMETF is to analyze all electromagnetic environment effects of Army communications-electronics (C-E) equipment, systems, and concepts in real and simulated tactical situations. The EMETF has scientists, engineers, and analysts organized to handle on-going operational tasks and long-term developmental work. This scientific and engineering staff is supported by a technical publications group, administrative and logistics services group, and six interrelated facilities. These six facilities, except for the Field Facility, are located in Tucson, Arizona, and are listed below:

1. The Instrumented Workshop (IWS) provides precisely controlled facilities to test military--including cryptographic--and commercial C-E systems and equipments. Using automated data collection and performance scoring (both analog and digital) capabilities, the IWS can handle equipments requiring individual link commitment as well as complex major systems requiring rapid and accurate data correlation and analysis.

2. The Scoring Facility (SF) enables the EMETF to consider the human operators and their responses to equipment operating characteristics. These operator responses are measured through use of articulation scores which represent the percentage of phonetically balanced words in a test message correctly received by the operators, or team of trained listeners.

3. The Spectrum Signature Facility (SSF) provides the capability of performing measurements of all pertinent C-E equipment characteristics under both laboratory and field conditions. These measurements are used for verification of design concepts early in the equipment life cycle as well as for the identification of spectrum signatures of foreign military C-E devices.

4. The Weapon System Electromagnetic Environment Simulator (WSEES) is a highly versatile simulation and measurement laboratory that tests systems and equipment operating in the RF microwave region and develops performance scoring data for such systems and equipment. WSEES RF signals duplicate those signals which can be expected to occur in a real-world environment, and the performance scoring data include measurements of the reaction of an adaptive system to a changing environment.

5. The Field Facility (FF), located near Gila Bend, Arizona, is used to test equipment deployments and equipment characteristics which cannot be simulated or measured in the laboratory. Testing capabilities include cosite interference, RF radiation, open-field emission, and susceptibility measurements. The FF also provides realistic field conditions for acquiring and validating data in support of analyses performed with computer models.

6. The EMETF Analytical Facility provides computer support based on a CDC 6500 computer--a large-scale, general-purpose digital computer system designed for multiprocessing and time-sharing, as well as general data processing and scientific applications. Input to the CDC 6500 is selected from an extensive library of computer models embracing analysis in near-field and far-field situations. The concept for these models has been validated by extensive field and laboratory measurements. The models simulate the electromagnetic environments of postulated situations and predict the performance of C-E and weapon system equipment in those situations.

APPENDIX D
SYSTEM EFFECTIVENESS SCORING METHODOLOGY

1. INTRODUCTION

1.1 General

a. Test beds of scenario troop deployments contain a full organizational complement of the communications-electronics (C-E) equipments of both friendly and enemy forces and represent an operational environment. Emitters and receivers are organized into nets as required by the C-E concept being simulated. Technical characteristics and geographical relationships of each individual radio frequency emitter and receiver are represented in these simulations.

b. The deployment of the full complement of tables of organization and equipment (TOE) equipment in a simulation, however, is not truly representative of the actual electromagnetic environment that would exist at any time in the force model. The deployed C-E links and emitters are activated only as necessary to provide the C-E support required by the tactical operation in progress. Therefore, each force model is further refined and adapted by the application of weighting factors to develop a simulation of the actual electromagnetic environment. This refinement culls out of the analysis those links that should not be formed.

c. Weighting is applied to all remaining links according to their relative tactical importance and to the probability that they carry active traffic. In this way the relative importance and electromagnetic influence of every probable link and emitter active in the environment are properly simulated.

d. Links are then scored to measure and quantify the potential electromagnetic interference and to determine the probability of successful communications compatibility with all other systems in the environment. System effectiveness scores are obtained for nets and for net types as weighted averages of the link probabilities of successful operation. Vulnerability of these nets and net types to enemy intercept and electronic countermeasures is also assessed.

1.2 The EMETF Analytical Facility

a. The analytical facility contains a library of computer models composed of a series of computer programs designed to process a deployment data file (a simulated C-E environment). Their purpose is to obtain a quantitative estimate of the communicability, compatibility, and vulnerability probabilities of C-E links, nets, or systems in an operational environment.

b. The series of computer programs is organized in six principal sections:

Preliminary data processing

Link formation and selection

Link sampling

Interference identification

Probability scoring

System effectiveness

1.3 Preliminary Data Processing

a. Preliminary data processing is required to compare a new test bed with existing data files. New data are developed to update net and link weighting factors, equipment scoring data, and analysis design codes in accordance with any new organizational doctrine or equipment in the test bed. The factors delineated in paragraph b below are updated on a new magnetic tape called a military values master file. Equipment codes are assigned to any new equipment and antenna types, and appropriate data are added to an equipment scoring matrix. Appropriate net, equipment, or other analysis category codes are assigned, based on the analysis plan. The codes facilitate the presentation of the output of SE scores in the proper array for ease of evaluation and comparison.

b. The six factors which are used to refine the force model for use by the computer models are described below:

(1) Cull Distance. Minimum cull distances are those distances (expressed in meters) below which there would be no requirement to communicate by radio and/or the equipment characteristics will not accommodate communications. Maximum cull distances are those distances (expressed in kilometers) beyond which the equipment characteristics will not accommodate communications and should not be attempted.

(2) Link Weight. The link weight factor is defined as a numerical factor (expressed in tenths from 0 to .9) which indicates the relative probability of the transmission of important traffic over that link with respect to all other possible links in that net.

(3) Net Weight. A numerical factor which reflects the relative importance of a net type to the overall accomplishment of the force mission.

(4) Posture Factor. A numerical value reflecting a unit's or net's relative degree of combat-related activity.

(5) Duty Cycle. The percentage of time that some link in a net is on the air (i.e., that some transmitter is being used).

(6) Intelligence Value. A numerical factor which ranks the C-E nets in a force model simulation in the order of their projected intelligence value to the enemy.

c. The confidence level and the accuracy desired within the limits of analysis time constraints are also assigned at this time to control the number of links to be sampled.

1.4 Link Formation and Selection

a. Within the design of the analysis, various elements of the environment can be selected for processing. This selection can be made by major organization, division, corps, or an entire army in the field. Selection can also be made by frequency band (for example, only SHF troposcatter multichannel systems), various combinations of friendly and enemy C-E and electronic warfare (EW) systems, or other categories of foreground and background environment.

b. All C-E nets of interest in the test bed are reviewed in the process of link formation, and all links not eliminated by minimum or maximum cull distances, or by a zero link weight are formed. The net weight, the posture factor, and the link weight of each link formed are multiplied by the computer. A link value for each link with respect to all other links formed is assigned. This value indicates both the relative importance of the link and also the probability that that link will be active in the environment of the time being simulated.

c. The links formed simulate the electromagnetic environment created by the tactical situation involved. This is a function of the relative importance of the net (net weight) to the mission of the forces as qualified by the relative combat activity in the unit being supported (the posture factor), and the probability of a link being in use and carrying important traffic (the link weight).

1.5 Link Sampling

Sufficient links, from among those formed, are sampled to obtain a final score that is within the confidence level and accuracy requirement desired. Links are assembled within various subgroups or cells. Typical cells are defined by such classifications as net, net type, or equipment class. The total number of links sampled is the aggregate of those required within all cells. Sampling within any cell is weighted by the

link values. The link sample favors the most important links in the most important nets with the highest degree of combat activity. Thus, the links (transmitter and receiver) with the highest probability of being active are sampled most heavily, and the most realistic electromagnetic environment is created.

1.6 Interferer Identification

Each friendly and enemy emitter which has formed a link is a potential interferer. The duty cycle of the net in which each transmitter operates is divided among the individual transmitters in accordance with link weighting. Thus, the probability of simultaneous transmission is established. Each transmitter is entered in a potential interferer file for use in probability scoring.

1.7 Probability Scoring

a. Links are scored first in the absence of interference. The probability of successful operation [P(SO)], or probability of successful information transfer, is measured from operator to operator. Signals are modeled from the output of the transmitter to the receiver input through the Longley-Rice irregular terrain propagation model, as modified, and the antenna models. The resultant distributions of desired signals are combined with empirically derived scoring data to obtain the P(SO) scores. These P(SO) scores are a direct reflection of the probability that the equipment characteristics, frequency, distance, and propagation conditions simulated will result in successful communications.

b. The degradation of this link communicability score is next measured by a calculation of degradation caused by unintentional interference and by intentional interference (jamming) by including a consideration of undesired signals. The discrete interfering equipments, both friendly and enemy, are identified by net, equipment type, and other categories of interest.

c. Interceptibility and the probability of successful direction finding (DF) are also calculated between friendly transmitters and enemy EW receivers in the presence and absence of background interference.

1.8 System Effectiveness

a. The P(SO) score of discrete C-E links and the measured degradation of those links by an individual interferer can be used to obtain an indication of C-E performance or vulnerability in the environment. Performance within a net, a net type, an equipment, an organization, or an entire C-E system can be obtained from a weighted average of the P(SO) of the sampled links in a desired category. Such a weighted average is

called the system effectiveness (SE) score. The SE score of a large number of links from a test bed (that is, the entire test bed or a broad equipment classification) is less useful than the SE score derived by net type or net. Very large numbers of links contain a mixture of equipment, frequency use, C-E requirements, tactical dispositions, organizations, and functions. This mixture tends to obscure the performance of the C-E system in a particular environmental condition created by the tactical situation. System effectiveness by net type throughout a test bed (for example, a mechanized battalion FM command net), represents the performance of a concept. System effectiveness by net reveals the effectiveness of particular battalion command nets in particular areas of the environment. System effectiveness by net reveals the electromagnetic compatibility (EMC) and electromagnetic vulnerability (EMV) problems that can develop in the discrete nets and is most useful in the evaluation of competing C-E systems.

b. SE scores are obtained for each net type in the test bed. The scores are assembled by major organization (echelon) for ease in evaluation and comparison. SE scores are also obtained for each net (in a net type) that obtains a poor communicability or compatibility score or is vulnerable to jamming, intercept, or direction finding. The P(SO) scores for the links within those nets that have poor performance, or that are vulnerable assist in determining the cause of poor performance, the source of interference, and the cause of EW vulnerability. System effectiveness scores for multichannel systems are also obtained by echelon, by net type, and by net.

APPENDIX E
GLOSSARY OF TERMS

Term	Definition
Articulation Index (AI)	A rating of the intelligibility of a test message based on the weighted signal-to-noise ratio of several frequency bands of equal contributions.
Communicability	A measure of the ability of C-E equipments, subsystems, and systems, together with electromagnetic devices, to operate in their intended operational environment without suffering degradation because of natural and uncontrolled man-made noise.
Compatibility	A measure of the ability of C-E devices, together with electromechanical devices, to operate in their intended operational environments without suffering or causing unacceptable degradation because of unintentional electromagnetic radiation or response.
Cosite	A situation which is defined as existing when two or more RF emitters share the same geographical location.
Direction Finding	Quantitative assessment of the signal and interference levels at the terminals of a receiver, enabling the receiver operator to process the signal and derive sufficient intelligence from it to allow determination of a usable direction-finding bearing.
Interceptibility	The degree of vulnerability of a transmitter to be detected, located, and identified, and have its transmissions analyzed.
Jamming	The intentional transmission of electromagnetic signals for the purpose of interfering with opposing forces' communications or radar.
Probability of Satisfactory Operation [P(SO)]	A performance score representing the likelihood of equaling or exceeding a specified level of performance over a period of time.

Term	Definition
System Effectiveness (SE)	A performance score which is an estimate of the ability of a communications-electronics system or subsystem to provide the desired service to the unit under study. It is a weighted average of the probability of satisfactory operation, P(SO), in which the weighting reflects the relative importance of the links to the success of the tactical mission.
Vulnerability	The degree to which a C-E system is open to exploitation of weaknesses for the purposes of attempting to degrade the system's performance or to gain information passed by or about the system or its mission. Vulnerability, for purposes of USAEPG analysis, consists of vulnerability to ECM and vulnerability to intercept.